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(21) International Application Number: PCT/DK92/00073 (22) International Filing Date: 10 March 1992 (10.03.92) (30) Priority data: 424/91 11 March 1991 (11.03.91) DK (71)(72) Applicant and Inventor: NIELSEN, Kristen [DK/DK]; Høstvej 6, DK-9220 Aalborg Øst (DK). (74) Agent: LARSEN & BIRKEHOLM A/S; Østeraa 25, P.O. Box 655, DK-9100 Aalborg (DK). (81) Designated States: AT, AT (European patent), AU, BB, BE (European patent), BF (OAPI patent), BG, BJ (OAPI pa- tent), BR, CA, CF (OAPI patent), CG (OAPI patent), CH, CH (European patent), CI (OAPI patent), CM (OA- PI patent), CS, DE, DE (Utility model), DE (European patent), DK, DK (European patent), ES, ES (European patent), FI, FR (European patent), GA (OAPI patent), GB, GB (European patent), GN (OAPI patent), GR (Eu- ropean patent), HU, IT (European patent), JP, KP, KR, LK, LU, LU (European patent), MC (European patent), MG, ML (OAPI patent), MN, MR (OAPI patent), MW, NL, NL (European patent), NO, PL, RO, RU, SD, SE, SE (European patent), SN (OAPI patent), TD (OAPI pa- tent), TG (OAPI patent), US.		Published <i>With international search report.</i>
(54) Title: APPARATUS AND METHOD FOR DETECTING BURIED, ELONGATED, ELECTROMAGNETIC DETEC- TABLE ITEMS <div data-bbox="305 1243 1338 1625" data-label="Image"> </div>		
(57) Abstract <p>There is provided an apparatus and a method for detecting buried, elongated, electromagnetically detectable objects. The objects may be detectable as they are, e.g. iron pipes or metallic cables, or they may be made detectable by a tracer. The present invention provides an apparatus where the transmitter means or the receiver means, or both (14), are provided with electromagnetic shield means (12) covering a spatial angle of at least 180° in relation to the transmitter means (14) or the receiver means (14). The shield (12) may be made so effective, that it may be fastened on the downward-facing side of an excavator. Thereby the transducer part (10) of the apparatus is not in such a vulnerable position and it may be easy to connect the transducers to a central processing and display unit close to the operator of the excavator.</p>		

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Apparatus and method for detecting buried, elongated,
electromagnetic detectable items

5 STATE OF THE ART

The invention concerns an apparatus and a method for detecting buried, elongated, electromagnetically detectable objects. The objects may be detectable as they are, e.g.
10 iron pipes or metallic cables, or they may be made detectable by a tracer. The apparatus comprises transmitter means and receiver means for electromagnetic signals where the transmitter and receiver means may be in the embodiment of coils. The transmitter means may form an electromagnetic
15 field which is coupled to the receiver means in the presence of a detectable object, and the magnetic coupling is then processed to indicate the presence of a such object, either visually, by alarm or by interrupting the work of an excavator.

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The known art is described in US patent nos. 4,600,356, 4,006,481, 3,907,136 and 3,858,737 which are all incorporated in the present description by reference.

25 The known apparatuses and methods have the drawback that they may create a signal depending on the presence of a detectable object but cannot precisely indicate the position of the object. This makes it rather difficult to find or to avoid the objects when digging in the ground. Another disadvantage by the known apparatuses is that they cannot be
30 fastened on an excavator because the iron mass of the machine acts as a coupling between transmitter and receiver. Some of the known apparatuses have their transducer part mounted on the hoe of the excavator, which makes the transducer and its connection to a signal processing unit in the
35 excavator vulnerable to the abrasion and shocks encountered

during work.

SUMMARY OF THE INVENTION

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In order to relieve the disadvantages, the present invention provides an apparatus where the transmitter means or the receiver means, or both, are provided with electromagnetic shield means covering a spatial angle of at least 180° in relation to the transmitter means or the receiver means. The
10 electromagnetic shield means may for example be provided in the form of a ferromagnetic shield in the shape of a dish-shaped plate, where the transmitter and receiver means are fastened by the concave side of the dish. The shield may be
15 made so effective, that e.g. the convex side of the dish may be fastened on the downward-facing side of the excavator. Thereby the transducer part of the apparatus is not in such a vulnerable position and it may be easy to connect the transducers to a central processing and display unit close
20 to the operator of the excavator.

In a preferred embodiment for the invention, each transmitter means or receiver means is provided with a mainly cup-shaped electromagnetic shield. By using several trans-
25 mitters and receivers it is possible to detect the position or direction of an object which is indicated by the coupling of a certain pair of transmitter means and receiver means. A mainly cup-shaped electromagnetic shield fitted at each transmitter means or receiver means prevents unwanted
30 coupling between the pair of receiver means and transmitter means.

When the transmitter means and the receiver means have a further electromagnetic shield means in common, there is at-
35 tained a very high degree of screening from the iron mass of the excavator.

It is also preferred that the transmitter means and receiver means are all placed along a mainly plane circumference and comprising an electronic control circuit so designed and
5 connected to the transmitter and receiver means in such a way that at least one detecting unit consisting of one receiver means and one transmitter means which are spaced apart along the circumference may detect a signal created by a said object which signal by the control circuit may be
10 transformed to another signal showing the direction of orientation of the object.

In a further embodiment of the invention, the control circuit comprises a subcircuit for electrically balancing a
15 faulty signal generated by an unwanted coupling between a transmitter means and a receiver means in the absence of a said object. The balancing subcircuit prevents disturbing error signals.

20 The method according to the invention is peculiar in that a detecting apparatus is situated at a downward-facing side of a vehicle and emits electromagnetic signals towards the ground. Said emission takes place alternatively from one of a plurality of transmitter means that are placed mainly
25 along a circumference. In the case of the presence of a detectable object, the signals are received by coupling to receiver means that are situated mainly along the same circumference. An electromagnetic coupling between a pair consisting of one transmitter means and one receiver means by a
30 control circuit is presented visually as a straight line having an orientation relative to the vehicle corresponding to the orientation of the said object. Thereby it is possible for the person controlling the excavator to be informed of the position of the buried objects. Because the
35 position of the apparatus on the excavator is known, it is also possible to plan the excavating work.

THE DRAWING

5 Embodiments of the invention are described in the following
with reference to the drawing where

Fig. 1 shows a partial section through an excavator provided
with an apparatus according to the invention,

10

Fig. 2 shows a first embodiment of the apparatus as seen
from below,

Fig. 3 shows a section on the line III-III in fig. 2,

15

Fig. 4 shows a second embodiment of the apparatus as seen
from below,

Fig. 5 shows a section on the line V-V in fig. 4,

20

Fig. 6 shows a schematic overview of the control circuit of
the apparatus according to the invention,

Fig. 7 shows a more detailed diagram comprising the
25 controller and transducer units of the control circuit,

Figs. 8 and 9 show diagrams of the receiver and transmitter
circuits, respectively, and

30 Fig. 10 shows a display with the relative positions of an
excavator and a detectable object.

DESCRIPTION OF EMBODIMENTS

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A first embodiment of the apparatus according to the inven-

tion comprises a transducer part 10 as shown in figs. 2 and 3.

The part 10 is preferably mounted at a downward-facing part 3 of the excavator 1 in the form of a tractor shown on fig. 1. The apparatus 10 comprises an electromagnetic shield 12 on the hollow side of which a number of transmitter-receiver units 14 are fastened. The units 14 are distributed along a circumference within the annular collar 16 of the shield 12. The shield 12 is made up of a ferromagnetic material of known kind, e.g. so-called μ -metal, that easily deflects magnetic field lines.

Each transmitter-receiver unit 14 has an individual, mainly cup-shaped electromagnetic shield 18 and is connected with a signal-transmitting cable 20 to a signal-processing unit 21. The unit 21 is in turn connected to a combined controller and display unit 5 situated close to the seat 6 of an operator of the excavator 1.

20

Each transmitter-receiver unit 14 has both a transmitter coil and a receiver coil for emitting and detecting electromagnetic fields. The spatial angle A covered by the shields 16 and 18 is more than 180° , see fig. 3. The shield 16 is effective as screening against the iron mass of the adjacent parts 3 of the excavator 1, and the shields 18 work as mutual screening between the transmitter-receiver units 14.

In order to give physical protection during work for the apparatus 10, the concave or hollow side of the shield 12 containing the units 14 may be filled up with a filler material of the kind that hardens to a abrasion-resistant and durable, but non-magnetic mass 24. The mass 24 is removed in fig. 2.

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A second and preferred embodiment of the apparatus according

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to the invention is shown in figs. 4 and 5 designated by the number 30. In this embodiment there is provided an inner electromagnetic shield 32 and an outer electromagnetic shield 34. The outer shield 34 surrounds the inner shield 32 at all sides except the side facing the ground when the apparatus 30 is in normal use. The space between the two shields 32,34 is filled with a known kind of elastomeric filler which may be applied in semi-fluid form and which then hardens into a solid, rubber-like mass 36.

10

The inner shield 32 has a number of transmitter-receiver units 14 distributed along a circumference as in the first embodiment of the apparatus. As shown, the number may be six, but any number more than two may be used. Also, the space between the units 14 and the shield 32 is filled with a same type of mass 24 as in the first embodiment.

Not shown wires for transmitting electric signals are passed through the shield 32 to a transmitter unit 38 and a receiver unit 39, which are both 38,39 fastened to the outer shield 34. Thereby both electromagnetic and physical protection is provided for the units 38,39.

The shields 32,34 cover a spatial angle of at least 180° from the view-point of any of the transmitter-receiver coils 14.

The electronic circuit provided for both embodiments is shown in figs. 6-9.

30

Fig. 6 shows the power supply for the circuit in a form of a battery 44 which through a key 45 and a fuse 46 is connected to the controller circuit 40 which is situated in the unit 5. The controller circuit 40 emits and receives signals to respectively from the transducer subcircuit 42 contained in the transducer part 10,30.

An enlarged and more detailed diagram comprising the circuits 40 and 42 is shown on fig. 7. An EMC and power interface is designated with the number 48 through which the electric current is supplied to a power supply unit 50. The exchange of power respectively signals is shown with arrows in the diagram.

Power is supplied to a microcomputer unit 52 and the power supply and the state of the microcomputer 52 are continuously controlled by a power watchdog unit 54. In the case of irregular or missing power supply, or if the microcomputer 52 is not functioning even when turned on, the unit 54 will give alert. The unit 52 makes it possible to emit and to receive signals through a receiver and transmitter unit 56 and a receiver and transmitter interface 58 which again is connected to the transmitter and receiver circuits 60, 62, respectively.

The acquired signals are processed by the unit 52 and are then displayed visually on a separate device 64. The mode of function of the unit 52 may be watched and changed by a keyboard and LED unit 66. Furthermore, a buzzer alarm 68 is connected to the unit 52 when the presence of a detectable object is to be called to the attention of the operator.

In the computer unit 52 there is provided a subcircuit for electrically balancing a faulty signal generated by an unwanted coupling between a transmitter means and a receiver means when no electromagnetic field-attracting objects are in view of the transmitter-receiver units 14.

The receiver circuit is schematically shown on fig. 8 where 70 designates a receiver coil and 71 designates amplifiers. The receiver circuit is contained in the unit 21 and in the receiver unit 39.

The transmitter circuit is shown on fig. 9 and comprises a transmitter coil 73 and an amplifier 74. The power supply to these two circuits is not specifically shown. The transmitter circuit is contained in the unit 21 and in the transmitter unit 38.

All the components of the circuits and subcircuits are available to the skilled in the art.

10

The function of the apparatus according to the invention may be as described hereafter. One unit 14 emits an electromagnetic field while another unit 14 which is placed geometrically opposite the emitting unit 14 has its receiving circuit activated for receiving signals. If a coupling between a transmitter and a receiver unit is created, for example by a pipe 7 or cable 8, the signal is transmitted to the computer unit 52 and causes the buzzer alarm 68 to go off and a line presenting the direction of the pipe 7 or cable 8 is shown on the display 64.

20

The image appearing on the display 64 is shown on fig. 10, where an outline 80 of the tractor 1 is shown. The display 64 is a graphical LCD-display of known type. A line 82 showing the direction of a pipe 7 or cable 8 is generated when the unit 52 finds out which pair of oppositely-positioned units 14 that couples with an object 7 or 8. As the direction of extension of the object 7,8 is approximately the same as a line through the coupled pair of units 14, the display 64 may show the direction of the object 7,8 in relation to the excavator 1.

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The operator in the excavator 1 may then adjust his work according to the position of the cables 8 or pipes 7. As the position of the transducer unit 10,30 on the excavator 1 is well-known, it is possible to make a rather precise estimate

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of the position of the pipes 7 or cables 8.

The apparatus and the method according to the invention may be varied in a number of ways without departing from the
5 scope of the invention.

CLAIMS

1. Apparatus for detecting buried, elongated, electro-magnetically detectable objects and comprising transmitter means and receiver means for electromagnetic signals, characterized in that the transmitter means or the receiver means, or both, are provided with electromagnetic shield means covering a spatial angle of at least 180° in relation to the transmitter means or the receiver means.
2. Apparatus according to claim 1 wherein the apparatus has a plurality of transmitter means and receiver means and wherein each transmitter means or receiver means is provided with a mainly cup-shaped electromagnetic shield.
3. Apparatus according to claim 2 wherein the transmitter means and the receiver means have a further electromagnetic shield means in common.
4. Apparatus according to any one of the preceding claims wherein the transmitter means and receiver means are all placed along a mainly plane circumference and comprising an electronic control circuit so designed and connected to the transmitter and receiver means in such a way that at least one detecting unit consisting of one receiver means and one transmitter means which are spaced apart along the circumference may detect a signal created by a said object which signal by the control circuit may be transformed to another signal showing the direction of orientation of the object.
5. Apparatus according to claim 4 wherein the control circuit comprises a subcircuit for electrically balancing a faulty signal generated by an unwanted coupling between a transmitter means and a receiver means in the absence of a said object.

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6. Method for detecting elongated, electromagnetically detectable objects buried in the ground, characterized in that a detecting apparatus situated at a downward-facing side of a vehicle emits electromagnetic signals towards the ground, said emission taking place alternatively from one of a plurality of transmitter means that are placed mainly along a circumference, while the said signals, in the case of the presence of a said object, are received by coupling to receiver means that are situated mainly along the same circumference, and that an electromagnetic coupling between a pair consisting of one transmitter means and one receiver means by a control circuit is presented visually as a straight line having an orientation relative to the vehicle corresponding to the orientation of the said object.

15

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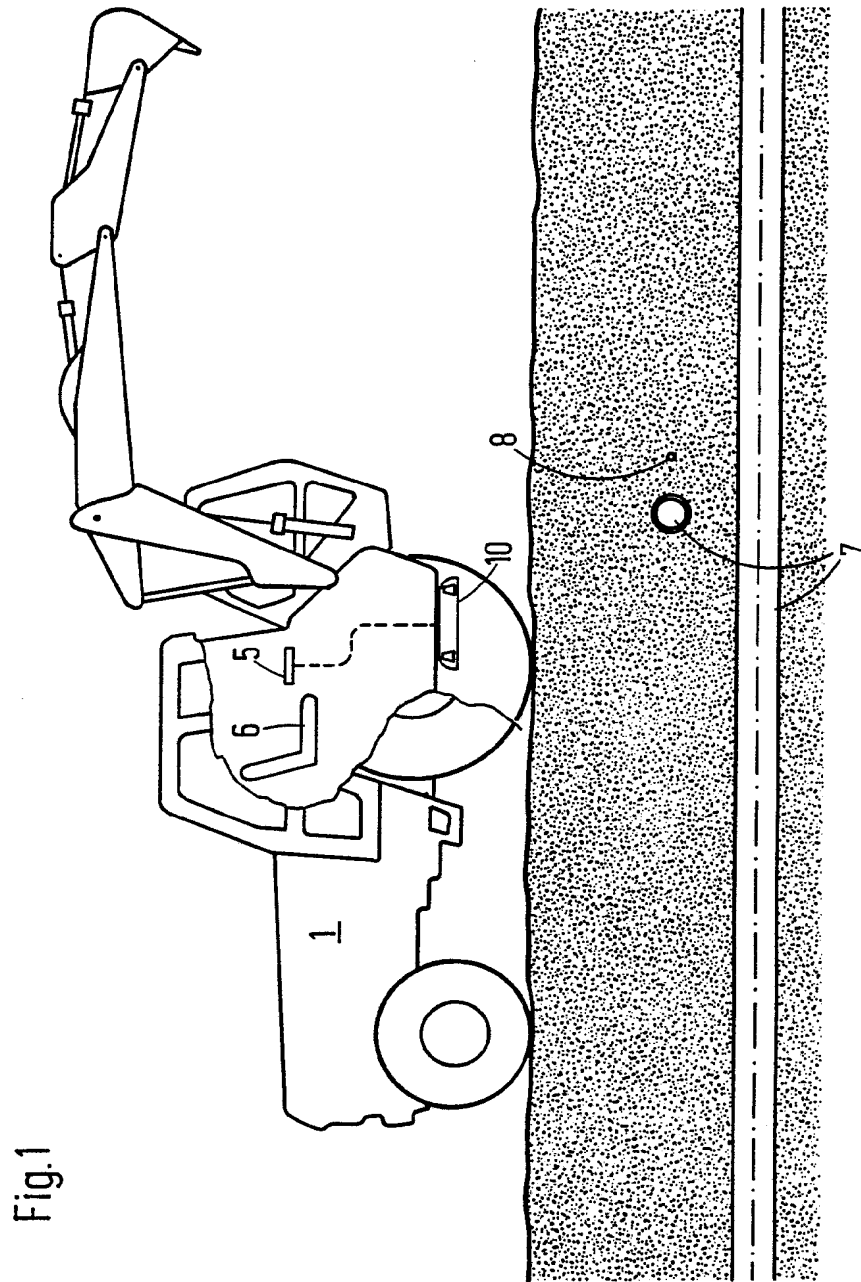


Fig. 1

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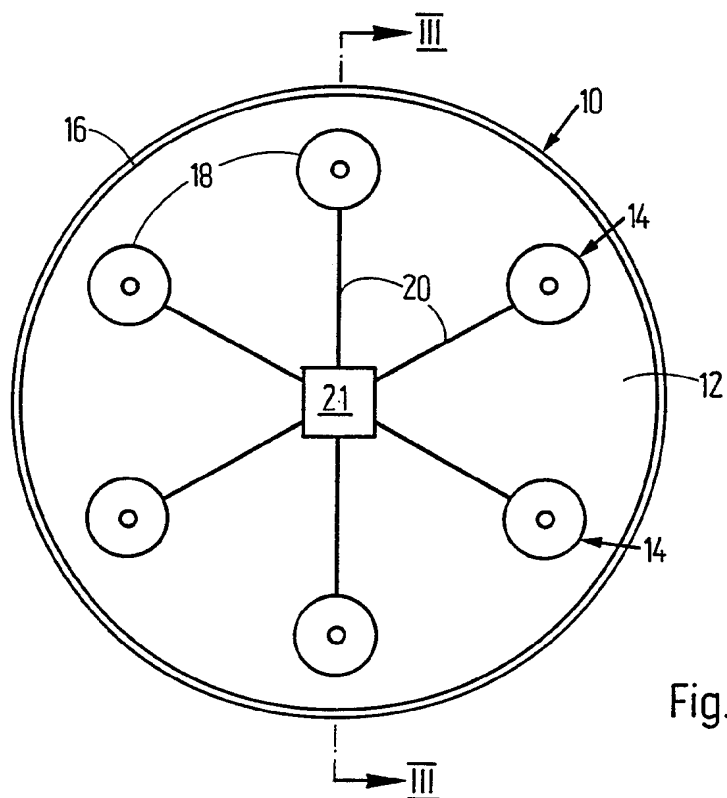


Fig. 2

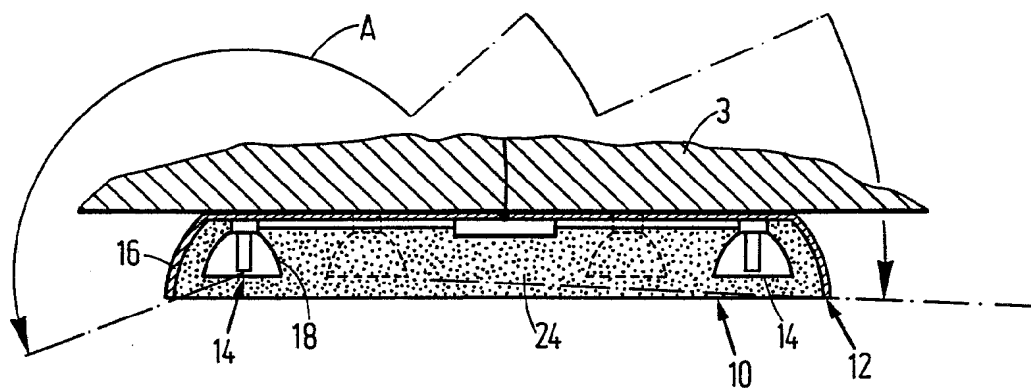
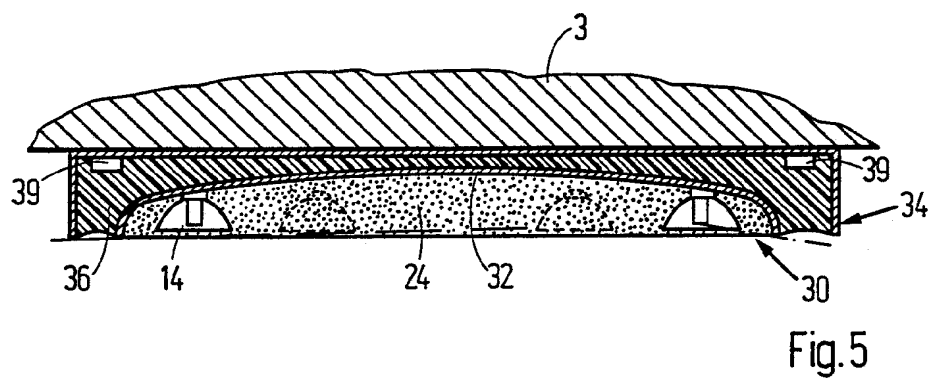
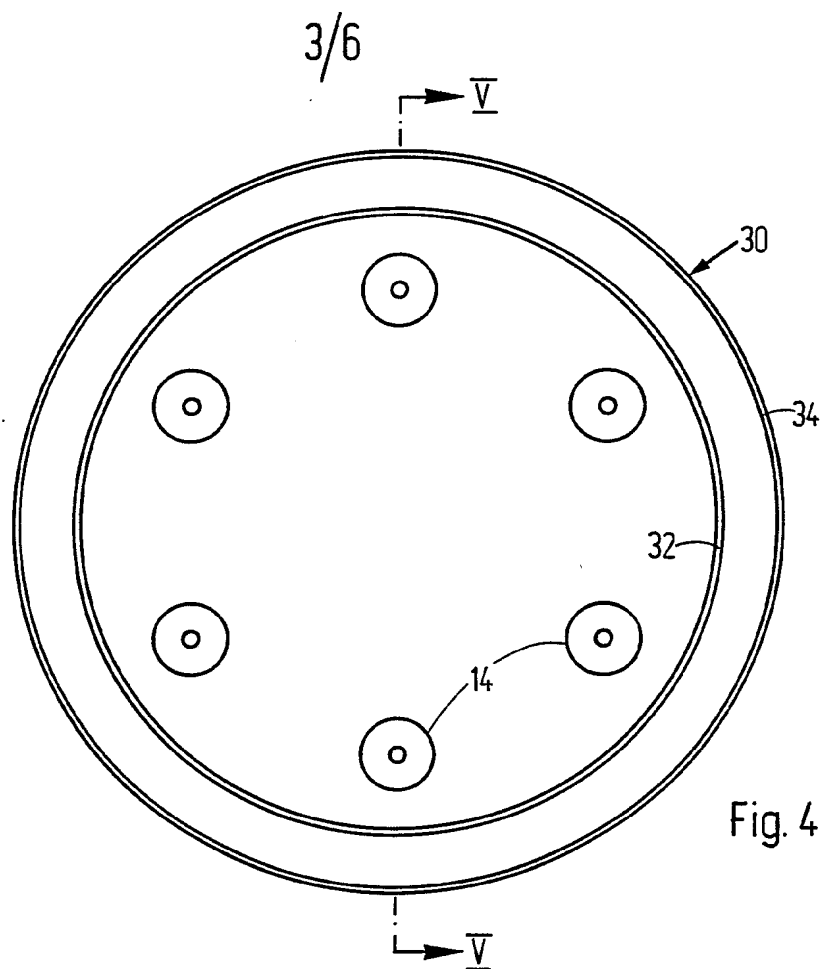
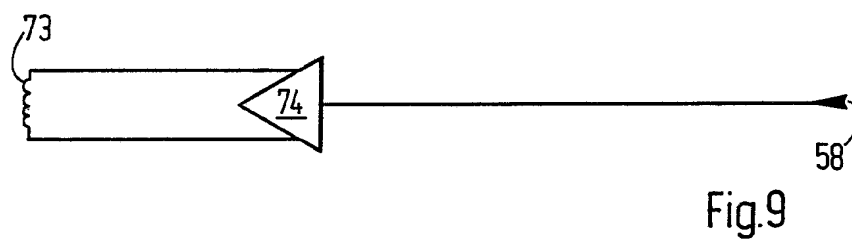
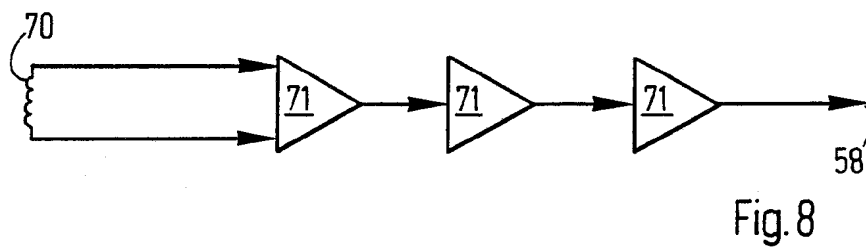
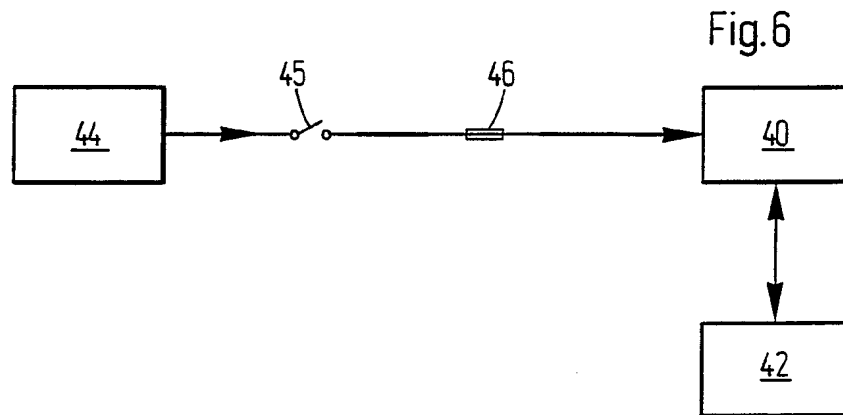


Fig. 3



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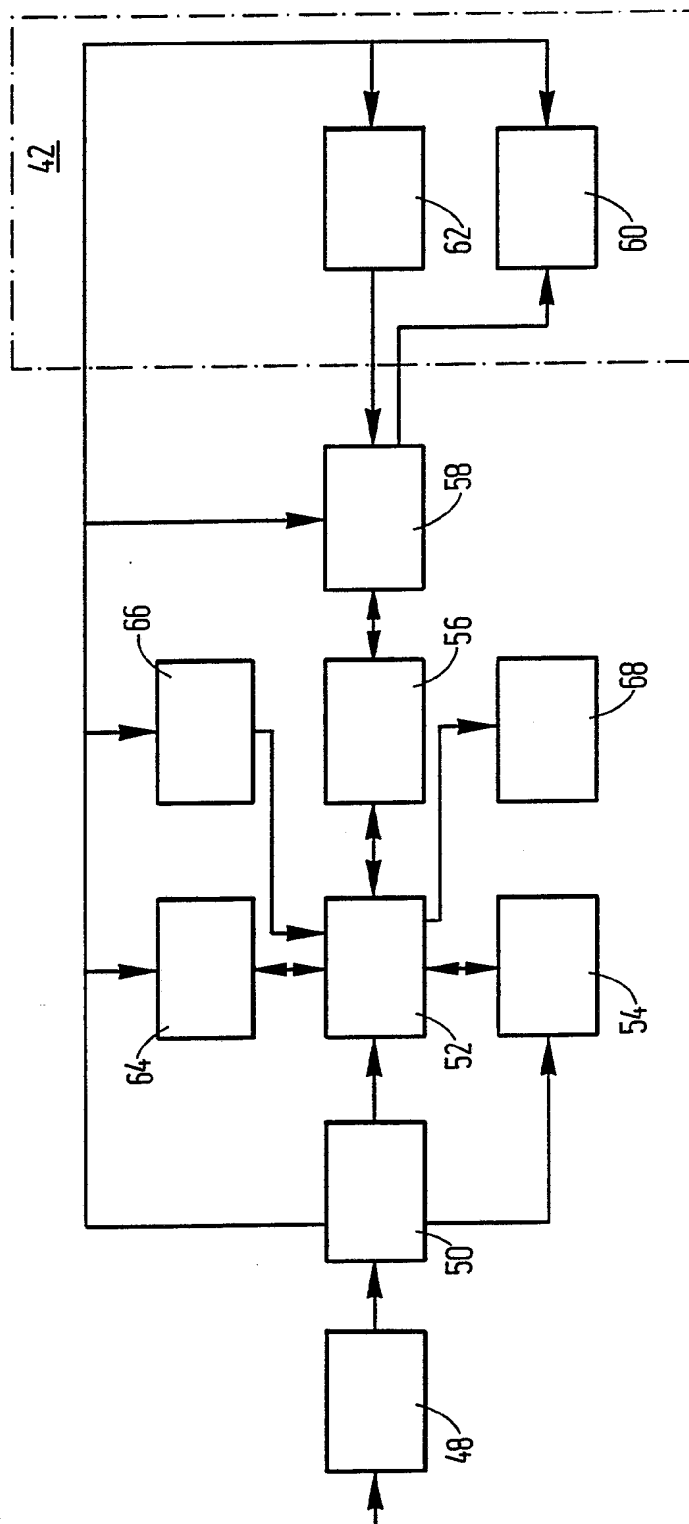


Fig. 7

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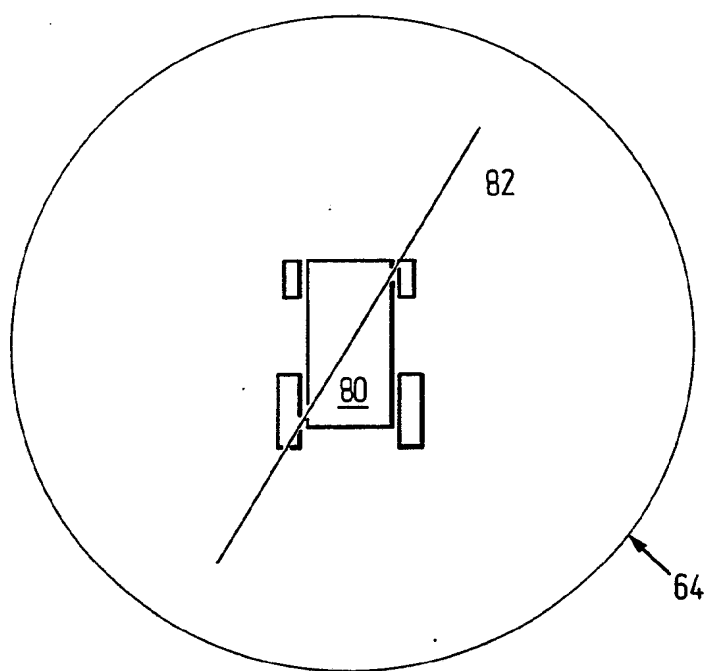


Fig.10

INTERNATIONAL SEARCH REPORT

International Application No PCT/DK 92/00073

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) ⁶ According to International Patent Classification (IPC) or to both National Classification and IPC IPC5: G 01 V 3/12, G 01 V 3/15																				
II. FIELDS SEARCHED <div style="text-align: center; border-top: 1px solid black; border-bottom: 1px solid black;">Minimum Documentation Searched⁷</div> <table style="width: 100%; border-collapse: collapse;"> <tr> <th style="width: 25%; text-align: left; border-bottom: 1px solid black;">Classification System</th> <th style="text-align: left; border-bottom: 1px solid black;">Classification Symbols</th> </tr> <tr> <td style="padding: 5px;">IPC5</td> <td style="padding: 5px;">G 01 V, H 01 Q, H 05 K</td> </tr> </table> <div style="text-align: center; border-top: 1px solid black; border-bottom: 1px solid black;">Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in Fields Searched⁸</div> <p style="padding: 5px;">SE,DK,FI,NO classes as above</p>			Classification System	Classification Symbols	IPC5	G 01 V, H 01 Q, H 05 K														
Classification System	Classification Symbols																			
IPC5	G 01 V, H 01 Q, H 05 K																			
III. DOCUMENTS CONSIDERED TO BE RELEVANT⁹ <table style="width: 100%; border-collapse: collapse;"> <tr> <th style="width: 10%; text-align: left; border-bottom: 1px solid black;">Category</th> <th style="text-align: left; border-bottom: 1px solid black;">Citation of Document,¹¹ with indication, where appropriate, of the relevant passages¹²</th> <th style="width: 15%; text-align: left; border-bottom: 1px solid black;">Relevant to Claim No.¹³</th> </tr> <tr> <td style="vertical-align: top; padding: 5px;">X</td> <td style="padding: 5px;">US, A, 1665662 (CECIL E. GODKIN) 10 April 1928, see page 1, line 1 - line 26; page 1, line 93 - line 103</td> <td style="vertical-align: top; padding: 5px;">1-3</td> </tr> <tr> <td style="vertical-align: top; padding: 5px;">Y</td> <td style="text-align: center; padding: 5px;">--</td> <td style="vertical-align: top; padding: 5px;">4-6</td> </tr> <tr> <td style="vertical-align: top; padding: 5px;">Y</td> <td style="padding: 5px;">US, A, 4085360 (MARK IAN HOWELL) 18 April 1978, see column 2, line 40 - column 3, line 25; abstract</td> <td style="vertical-align: top; padding: 5px;">4-6</td> </tr> <tr> <td style="vertical-align: top; padding: 5px;">Y</td> <td style="padding: 5px;">DE, A1, 3600446 (DOEHLER, PETER) 16 July 1987, see column 3, line 46 - column 4, line 9</td> <td style="vertical-align: top; padding: 5px;">4-6</td> </tr> <tr> <td style="vertical-align: top; padding: 5px;">A</td> <td style="padding: 5px;">US, A, 4894619 (ERKKI I. LEINONEN ET AL) 16 January 1990, see column 1, line 6 - column 2, line 36; column 3, line 26 - line 40</td> <td style="vertical-align: top; padding: 5px;">5</td> </tr> </table>			Category	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³	X	US, A, 1665662 (CECIL E. GODKIN) 10 April 1928, see page 1, line 1 - line 26; page 1, line 93 - line 103	1-3	Y	--	4-6	Y	US, A, 4085360 (MARK IAN HOWELL) 18 April 1978, see column 2, line 40 - column 3, line 25; abstract	4-6	Y	DE, A1, 3600446 (DOEHLER, PETER) 16 July 1987, see column 3, line 46 - column 4, line 9	4-6	A	US, A, 4894619 (ERKKI I. LEINONEN ET AL) 16 January 1990, see column 1, line 6 - column 2, line 36; column 3, line 26 - line 40	5
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X	US, A, 1665662 (CECIL E. GODKIN) 10 April 1928, see page 1, line 1 - line 26; page 1, line 93 - line 103	1-3																		
Y	--	4-6																		
Y	US, A, 4085360 (MARK IAN HOWELL) 18 April 1978, see column 2, line 40 - column 3, line 25; abstract	4-6																		
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A	US, A, 4894619 (ERKKI I. LEINONEN ET AL) 16 January 1990, see column 1, line 6 - column 2, line 36; column 3, line 26 - line 40	5																		
<div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p>* Special categories of cited documents:¹⁰</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> </div> <div style="width: 45%;"> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance, the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance, the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"&" document member of the same patent family</p> </div> </div>																				
IV. CERTIFICATION <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 50%; padding: 5px;"> Date of the Actual Completion of the International Search 17th June 1992 </td> <td style="width: 50%; padding: 5px;"> Date of Mailing of this International Search Report 1992 -06- 23 </td> </tr> <tr> <td style="padding: 5px;"> International Searching Authority <div style="text-align: center; padding-top: 10px;"> SWEDISH PATENT OFFICE </div> </td> <td style="padding: 5px;"> Signature of Authorized Officer <div style="text-align: center; padding-top: 10px;"> STEFAN SVAHN </div> </td> </tr> </table>			Date of the Actual Completion of the International Search 17th June 1992	Date of Mailing of this International Search Report 1992 -06- 23	International Searching Authority <div style="text-align: center; padding-top: 10px;"> SWEDISH PATENT OFFICE </div>	Signature of Authorized Officer <div style="text-align: center; padding-top: 10px;"> STEFAN SVAHN </div>														
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III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
A	DE, A1, 3920081 (SEICHTER, HELMUT ET AL) 3 January 1991, see column 1, line 3 - line 38; column 3, line 1 - line 56 -- -----	1-6

**ANNEX TO THE INTERNATIONAL SEARCH REPORT
ON INTERNATIONAL PATENT APPLICATION NO.PCT/DK 92/00073**

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the Swedish Patent Office EDP file on 29/05/92
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US-A- 1665662	28-04-10	NONE	
US-A- 4085360	78-04-18	NONE	
DE-A1- 3600446	87-07-16	NONE	
US-A- 4894619	90-01-16	CA-A- 1279387	91-01-22
		DE-A- 3727416	88-02-18
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		SE-A- 8703030	88-02-16
DE-A1- 3920081	91-01-03	EP-A- 0403788	90-12-27
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